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This document describes the statistical analyses of bulk sample data taken from school buildings in two locations: New York City and Maryland. The bulk samples were analyzed for asbestos by various laboratories and the results given to the Research Triangle Institute for analysis. In particular, Section I of this report describes the analysis of the New York City data which reported the presence or absence of asbestos (Amosite or Chrysotile) in 474 bulk samples taken from various types of building material in New York City schools. Section II describes the analysis of the Maryland data which contains analysis of 37 split-asbestos bulk samples taken from Maryland public schools. The split-samples in Maryland were sent to two or more laboratories which determined presence or absence of asbestos (Amphibole and Chrysotile) as well as actual levels of asbestos found.

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ASBESTOS ANALYTICAL PROGRAMS BULK SAMPLE ANALYSIS: NEW YORK CITY AND MARYLAND

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PREFACE

This document describes the statistical analyses of bulk sample data taken from school buildings in two locations: New York City and Maryland. The bulk samples were analyzed for asbestos by various laboratories and the results given to the Research Triangle Institute for analysis. In particular, Section I of this report describes the analysis of the New York City data which reported the presence or absence of asbestos (Amosite or Chrysotile) in 474 bulk samples taken from various types of building material in New York City schools. Section II describes the analysis of the Maryland data which contains analysis of 37 split-asbestos bulk samples taken from Maryland public schools. The split-samples in Maryland were sent to two or more laboratories which determined presence or absence of asbestos (Amphibole and Chrysotile) as well as actual levels of asbestos found.

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I. NEW YORK CITY

Data Supplied by:

Roger A. Chiljean
Anthony R. Smith

New York City
Board of Education
Division of School Buildings

I.1 Introduction

This data comes from the polarized light microscopic (PLM) analysis of building material bulk samples taken during 1977-1979 from New York City schools. The samples were analyzed for asbestos by Walter C. McCrone Associates for the New York City Board of Education, Division of School Buildings. For each sample analyzed, the following data items were available:

1. School identification,
2. District,
3. Type of material (acoustic plaster, spray fireproofing, soft acoustic spray, or thermal insulation, and miscellaneous pipe covering, tile, etc.),
4. Whether asbestos is present or not,
5. Type of asbestos present (amosite, chrysotile), and
6. Percent of asbestos present.

Other data items available on the New York City raw data sheets such as dates of collection, mailing, and analysis of samples were not included on the computer file.

There were 474 samples in this data set. A listing of the data with an explanation of the codes used is given in Appendix A.

I.2 Distribution of Asbestos by Type of Material

The data on presence/absence of asbestos are crosstabulated with the type of material in Table I.1.A. The percent of samples with asbestos varied from 31.6% among acoustic plaster samples to 79.3% among miscellaneous samples. However, it is important to note here for friable materials (codes 2, 3, and 4) that the percent of samples with asbestos present was 77.4% as shown in Table I.1.B. Compared to the other three types of material, a statistically significant smaller percentage of acoustic plaster (which is non-friable) samples ($p<.0001$) had asbestos.

I.3 Distribution of Asbestos in Friable and Non-Friable Samples

The distribution of total asbestos in the 235 friable and non-friable samples with asbestos is given in Figure I.1.A. Figure I.2.A gives the distributions of amosite and Figure I.3.A gives the distribution of chrysotile. Similar distributions are given for non-friable samples in Figures I.1.B, I.2.B, and I.3.B while distributions for friable samples are given in Figures I.1.C, I.2.C, and I.3.C.

The related summary statistics for all friable/non-friable samples are given in Table I.2.A. Summary statistics for non-friable samples containing asbestos are given in Table I.2.B with those for friable samples containing asbestos in Table I.2.C. While 86.8% of the non-friable samples with asbestos had less than 10% asbestos, only 8.3% of the friable samples with asbestos had less than 10% asbestos. All 4 of the non-friable samples containing amosite had less than 10% amosite with 22.5% of the friable samples with amosite containing less than 10% amosite. For samples containing chrysotile, 86.4% of the non-friable samples contained less than 10% chrysotile with just 9.3% of the friable samples containing less than 10% chrysotile. The percentages of non-friable samples with 1% asbestos were 50.0% for amosite, 14.8% for chrysotile and 14.3% for total asbestos. For friable samples, none of the samples contained just 1% asbestos. The range of percent asbestos present in non-friable samples was 1 to 80 for chrysotile and total asbestos and 1 to 3 for amosite. Ranges of percent asbestos present in friable samples were 5 to 90 for amosite, 3 to 90 for chrysotile, and 3 to 95 for total asbestos. As indicated, although asbestos can be present in both friable and non-friable samples, much higher percentages of asbestos tend to be present in those friable samples containing asbestos.

I.4 Summary

Four hundred seventy-four samples of building materials gathered from New York City schools during 1977-1979 were analyzed by Walter C. McCrone Associates for asbestos content. For all of the samples, 49.6% had asbestos. Compared to samples of other types of material, a lower percentage of acoustic plaster (non-friable) samples had asbestos (Table I.1.B) and, for those acoustic plaster samples with asbestos, the mean level was 8.98% with a standard deviation of 15.68 (Table I.2.B). For friable materials, the percentage of samples with asbestos was between 70 and 80% (Table I.1.A) and, of those with asbestos, the mean level was 46.61% with a standard deviation of 27.86 (Table I.2.C).

The mean percent of asbestos in both friable and non-friable samples by type of asbestos was 26.5% for amosite, 30.7% for chrysotile, and 32.0% for all asbestos (Table I.2.A). For non-friable samples alone, this mean percent of asbestos by type was 1.75% for amosite and 9.2% for chrysotile (Table I.2.B). The mean percent asbestos in friable samples by type was 29.0% for amosite and 46.8% for chrysotile (Table I.2.C). Samples with less than 10% total asbestos constituted about 39% of all postive bulk samples, over 85% of the positive non-friable bulk samples, and under 25% of the positive friable bulk samples. The range of per-

cent total asbestos present was 1 to 95 in the 474 total samples, 1 to 80 in the acoustical plaster samples, and 3 to 95 in the friable samples.

Table I.1.A. DISTRIBUTION OF ASBESTOS PRESENT ACCORDING TO TYPE OF MATERIAL

Presence of Asbestos	Type of Material *				All
	1	2	3	4	
No	197[1/]	14	11	17	239
	82.4[2/]	5.9	4.6	7.1	50.4
	68.4[3/]	21.2	28.9	20.7	
Yes	91	52	27	65	235
	38.7	22.1	11.5	27.7	49.6
	31.6	78.8	71.1	79.3	
Total	288	66	38	82	474
	60.8	13.9	8.0	17.3	

Chi-square = 95.7 with 3 degrees of freedom; $p < .0001$

* Type of Material codes are:

1 - Acoustic plaster
2 - Spray fireproofing
3 - Soft acoustic spray/thermal insulation
4 - Miscellaneous - pipe covering, etc.

Note, in general, materials 2, 3, and 4 are friable while material 1 (acoustic plaster) is not friable.

1/ frequency

2/ row percent

3/ column percent

Table I.1.B. DISTRIBUTION OF ASBESTOS PRESENT ACCORDING TO MATERIAL TYPE

Presence of Asbestos	Material Type		All
	Non-Friable	Friable	
No	197[1/]	42	239
	82.4[2/]	17.6	50.4
	68.4[3/]	22.6	
Yes	91	144	235
	38.7	61.3	49.6
	31.6	77.4	
Total	288	186	474
	60.8	39.2	

Chi-square = 94.922 with 1 degree of freedom; $p < .0001$

1/ frequency

2/ row percent

3/ column percent

Table I.2.A. SUMMARY STATISTICS FOR FRIABLE AND NON-FRIABLE SAMPLES WITH ASBESTOS

Type of Asbestos	Mean	Standard Deviation	Range of Values	Percent Samples With Less Than 10% Asbestos	No. of Samples
All Asbestos	32.04	30.11	1 to 95	38.7 (5.5)**	235
Amosite	26.52	26.66	1 to 90	29.5 (4.5)	44
Chryso-tile	30.74	29.81	1 to 90	42.2 (6.3)	206

** percent with 1%

Table I.2.B. SUMMARY STATISTICS FOR NON-FRIABLE SAMPLES WITH ASBESTOS

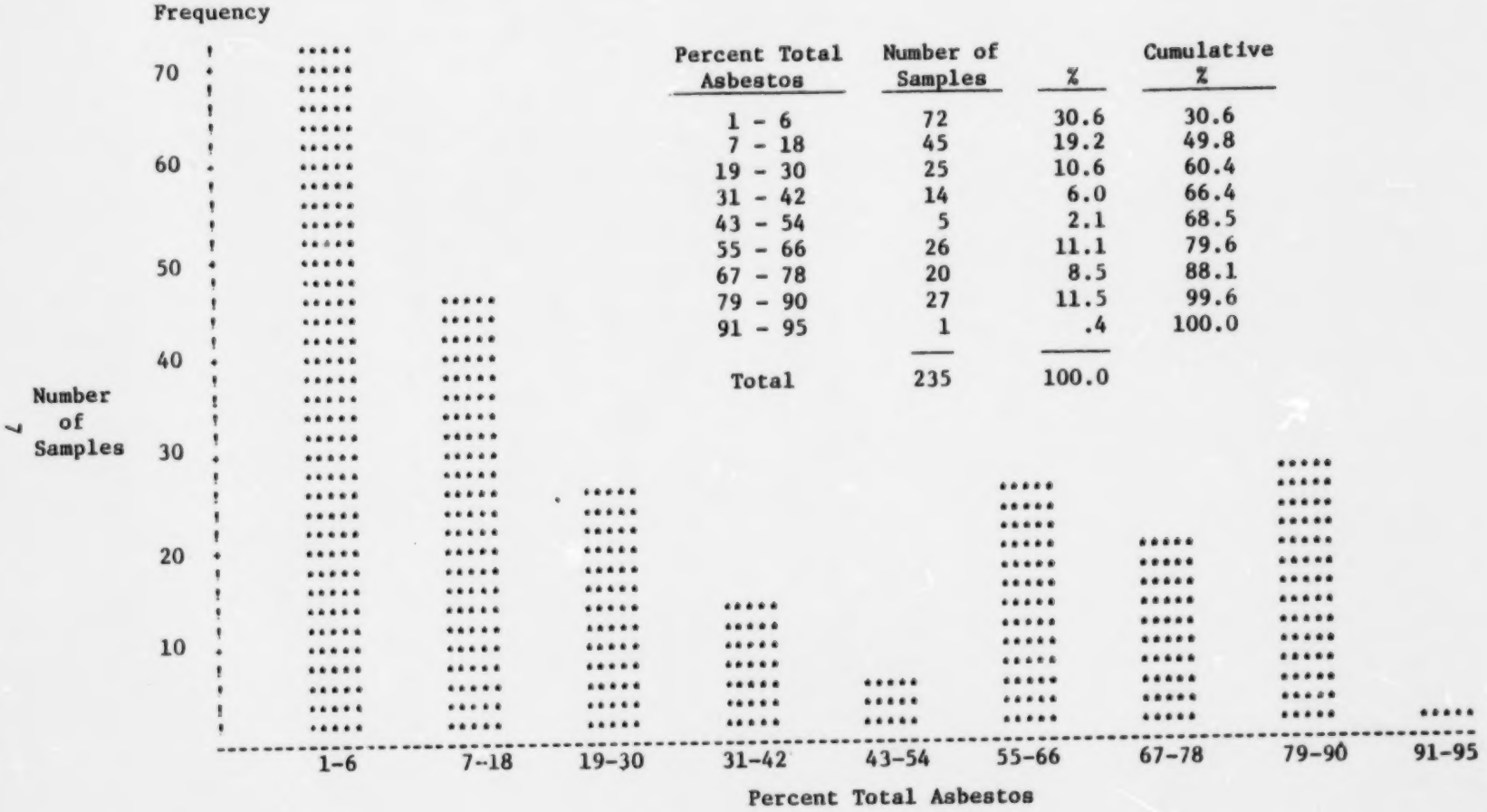
Type of Asbestos	Mean	Standard Deviation	Range of Values	Percent Samples With Less Than 10% Asbestos	No. of Samples
All Asbestos	8.98	15.68	1 to 80	86.8 (14.3)**	91
Amosite	1.75	0.96	1 to 3	100.0 (50.0)	4
Chryso-tile	9.20	15.90	1 to 80	86.4 (14.8)	88

** percent with 1%

Table I.2.C. SUMMARY STATISTICS FOR FRIABLE SAMPLES WITH ASBESTOS

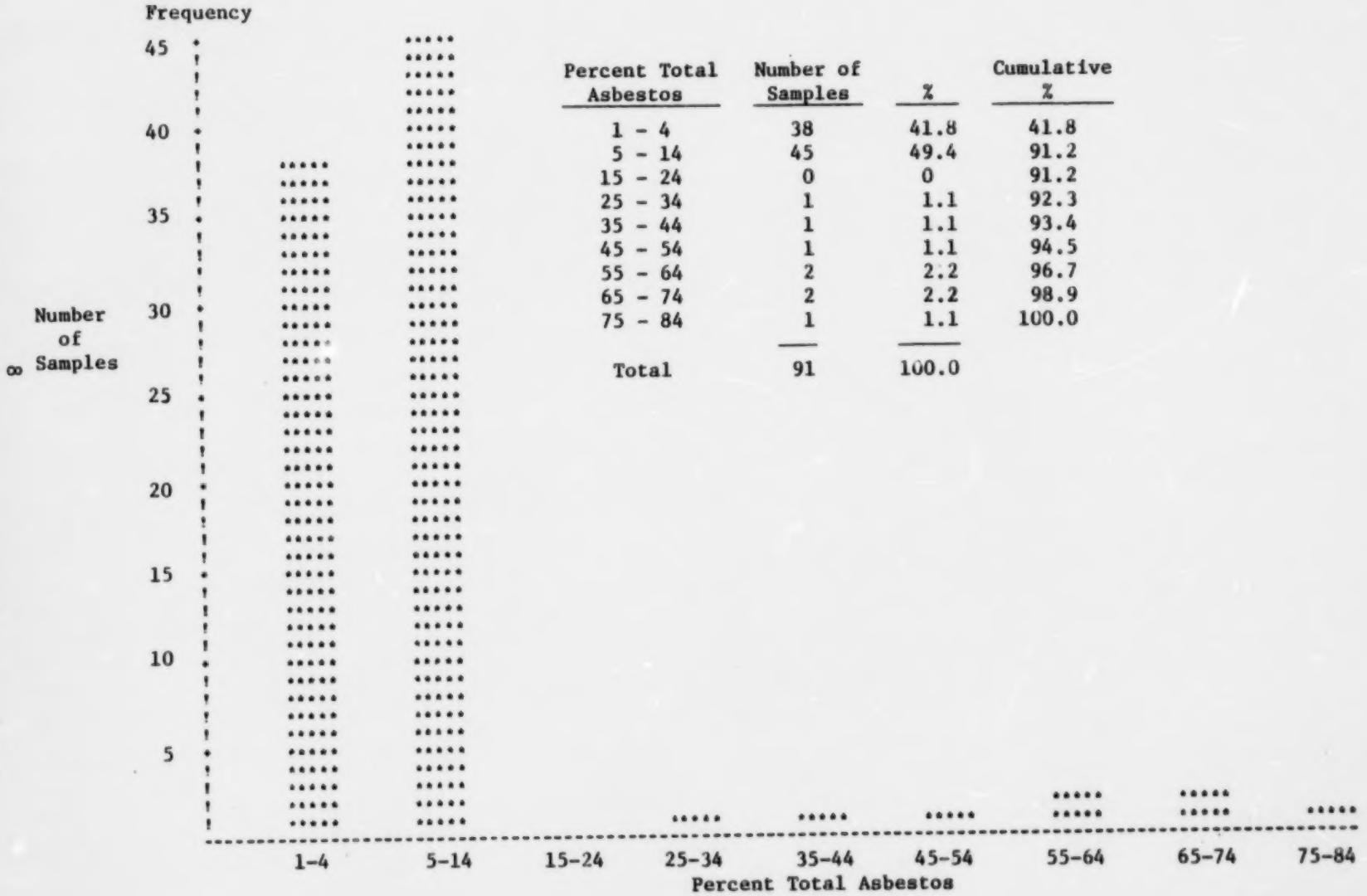
Type of Asbestos	Mean	Standard Deviation	Range of Values	Percent Samples With Less Than 10% Asbestos	No. of Samples
All Asbestos	46.61	27.86	3 to 95	8.3 (0.0)**	144
Amosite	29.00	26.73	5 to 90	22.5 (0.0)	40
Chryso-tile	46.80	27.58	3 to 90	9.3 (0.0)	118

** percent with 1%



Percent Total Asbestos	Number of Samples	%	Cumulative %
1 - 6	72	30.6	30.6
7 - 18	45	19.2	49.8
19 - 30	25	10.6	60.4
31 - 42	14	6.0	66.4
43 - 54	5	2.1	68.5
55 - 66	26	11.1	79.6
67 - 78	20	8.5	88.1
79 - 90	27	11.5	99.6
91 - 95	1	.4	100.0
Total	235	100.0	

Figure I.1.A. Distribution of the Percent Total Asbestos in the 235 Friable and Non-Friable Samples Containing Some Asbestos



Percent Total Asbestos	Number of Samples	%	Cumulative %
1 - 4	38	41.8	41.8
5 - 14	45	49.4	91.2
15 - 24	0	0	91.2
25 - 34	1	1.1	92.3
35 - 44	1	1.1	93.4
45 - 54	1	1.1	94.5
55 - 64	2	2.2	96.7
65 - 74	2	2.2	98.9
75 - 84	1	1.1	100.0
Total	91	100.0	

Figure I.1.B. Distribution of the Percent Total Asbestos in the 91 Non-Friable Samples Containing Some Asbestos

Percent Total Asbestos	Number of Samples	%	Cumulative %
1 - 6	8	5.6	5.6
7 - 18	26	18.0	23.6
19 - 30	24	16.7	40.3
31 - 42	13	9.0	49.3
43 - 54	4	2.8	52.1
55 - 66	24	16.7	68.8
67 - 78	18	12.5	81.3
79 - 90	26	18.0	99.3
91 - 100	1	0.7	100.0
Total	144	100.0	

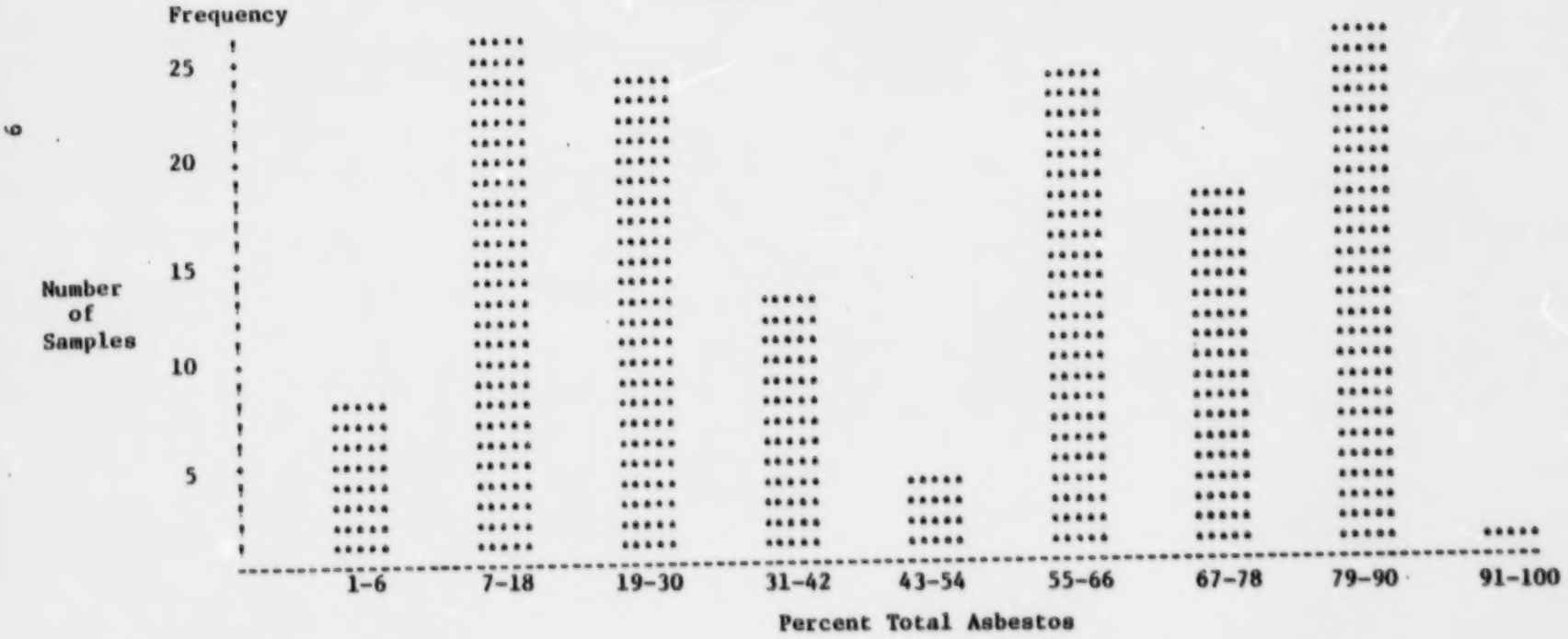
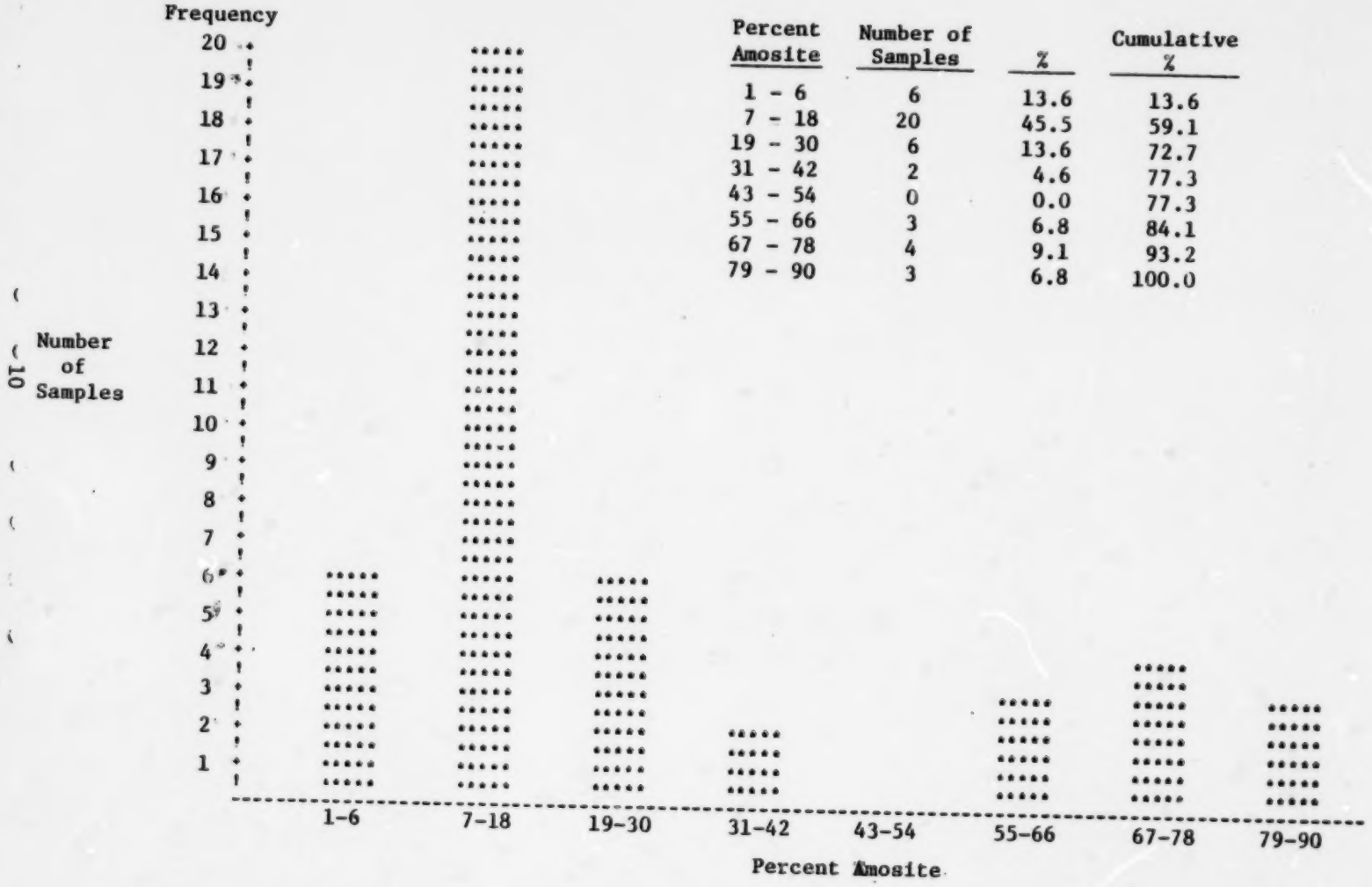
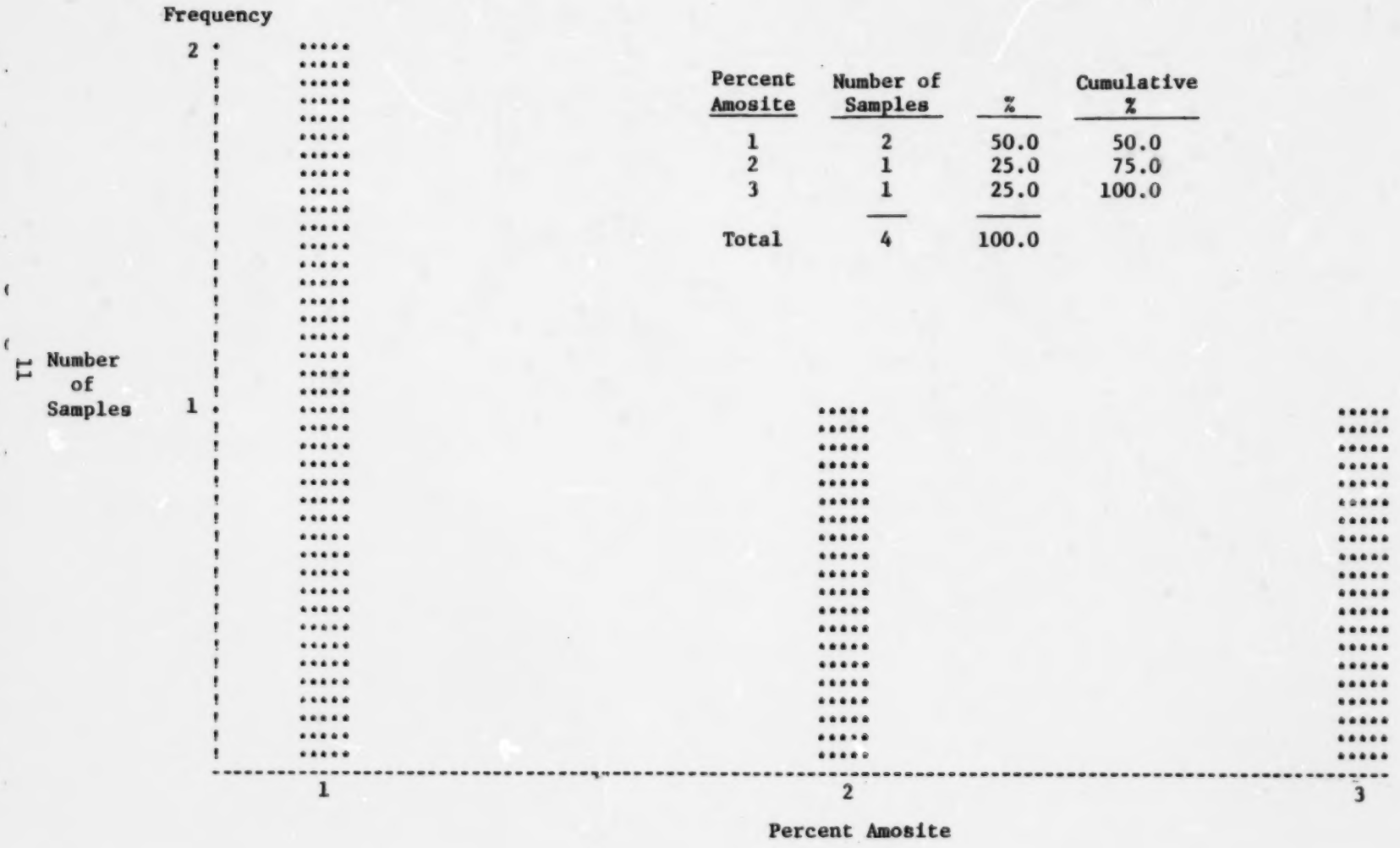


Figure I.1.C. Distribution of the Percent Total Asbestos in the 144 Friable Samples Containing Some Asbestos



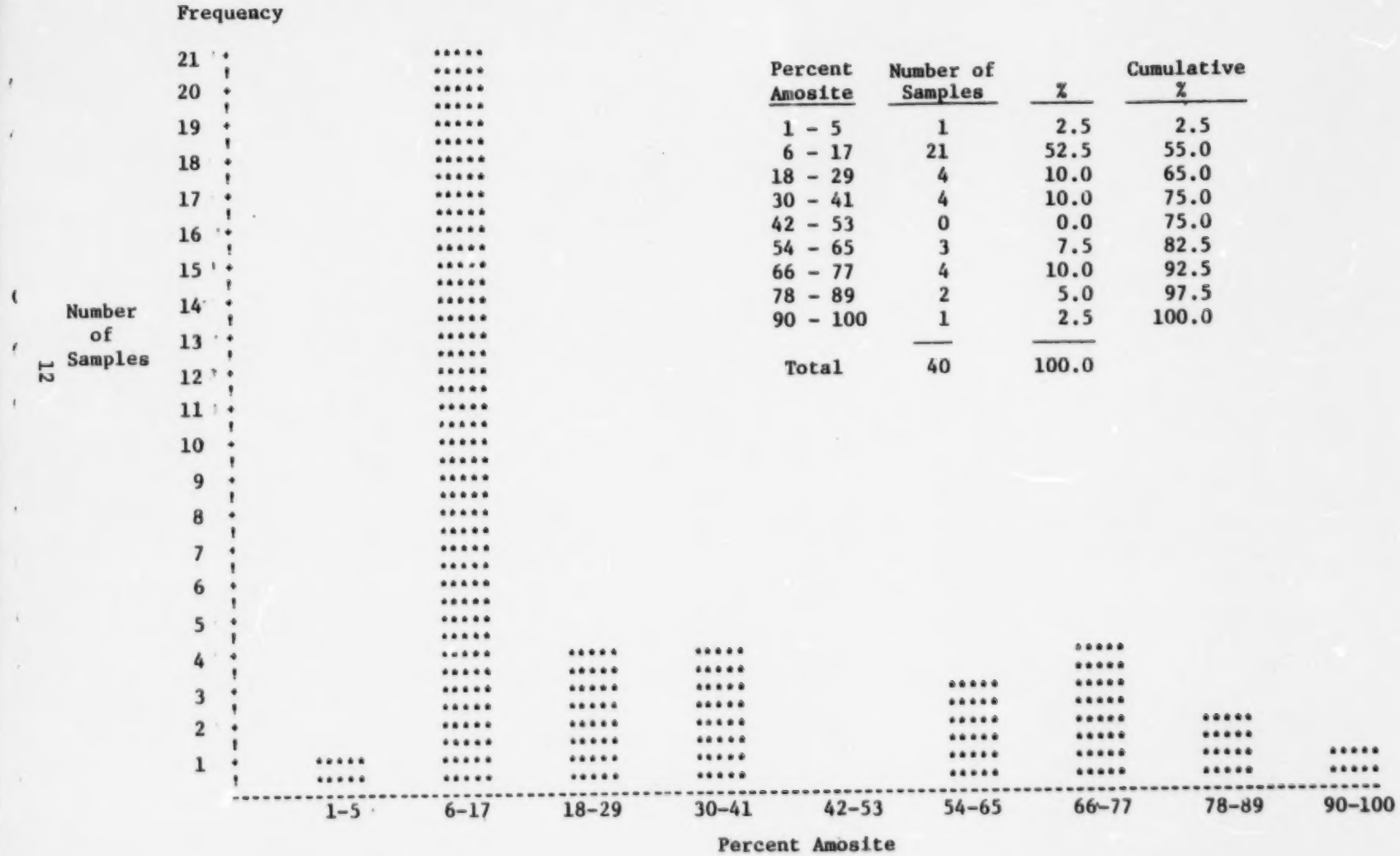
Percent Amosite	Number of Samples	%	Cumulative %
1 - 6	6	13.6	13.6
7 - 18	20	45.5	59.1
19 - 30	6	13.6	72.7
31 - 42	2	4.6	77.3
43 - 54	0	0.0	77.3
55 - 66	3	6.8	84.1
67 - 78	4	9.1	93.2
79 - 90	3	6.8	100.0

Figure I.2.A. Distribution of the Percent Amosite in the 44 Friable and Non-Friable Samples Containing Amosite



Percent Amosite	Number of Samples	%	Cumulative %
1	2	50.0	50.0
2	1	25.0	75.0
3	1	25.0	100.0
Total	4	100.0	

Figure I.2.B. Distribution of the Percent Amosite in the 4 Non-Friable Samples Containing Amosite



Percent Amosite	Number of Samples	%	Cumulative %
1 - 5	1	2.5	2.5
6 - 17	21	52.5	55.0
18 - 29	4	10.0	65.0
30 - 41	4	10.0	75.0
42 - 53	0	0.0	75.0
54 - 65	3	7.5	82.5
66 - 77	4	10.0	92.5
78 - 89	2	5.0	97.5
90 - 100	1	2.5	100.0
Total	40	100.0	

Figure I.2.C. Distribution of the Percent Amosite in the 40 Friable Samples Containing Amosite

Percent Chrysotile	Number of Samples	%	Cumulative %
1 - 6	68	33.0	33.0
7 - 18	39	18.9	51.9
19 - 30	19	9.3	61.2
31 - 42	14	6.8	68.0
43 - 54	2	0.9	68.9
55 - 66	26	12.7	81.6
67 - 78	16	7.7	89.3
79 - 90	22	10.7	100.0
Total	206	100.0	

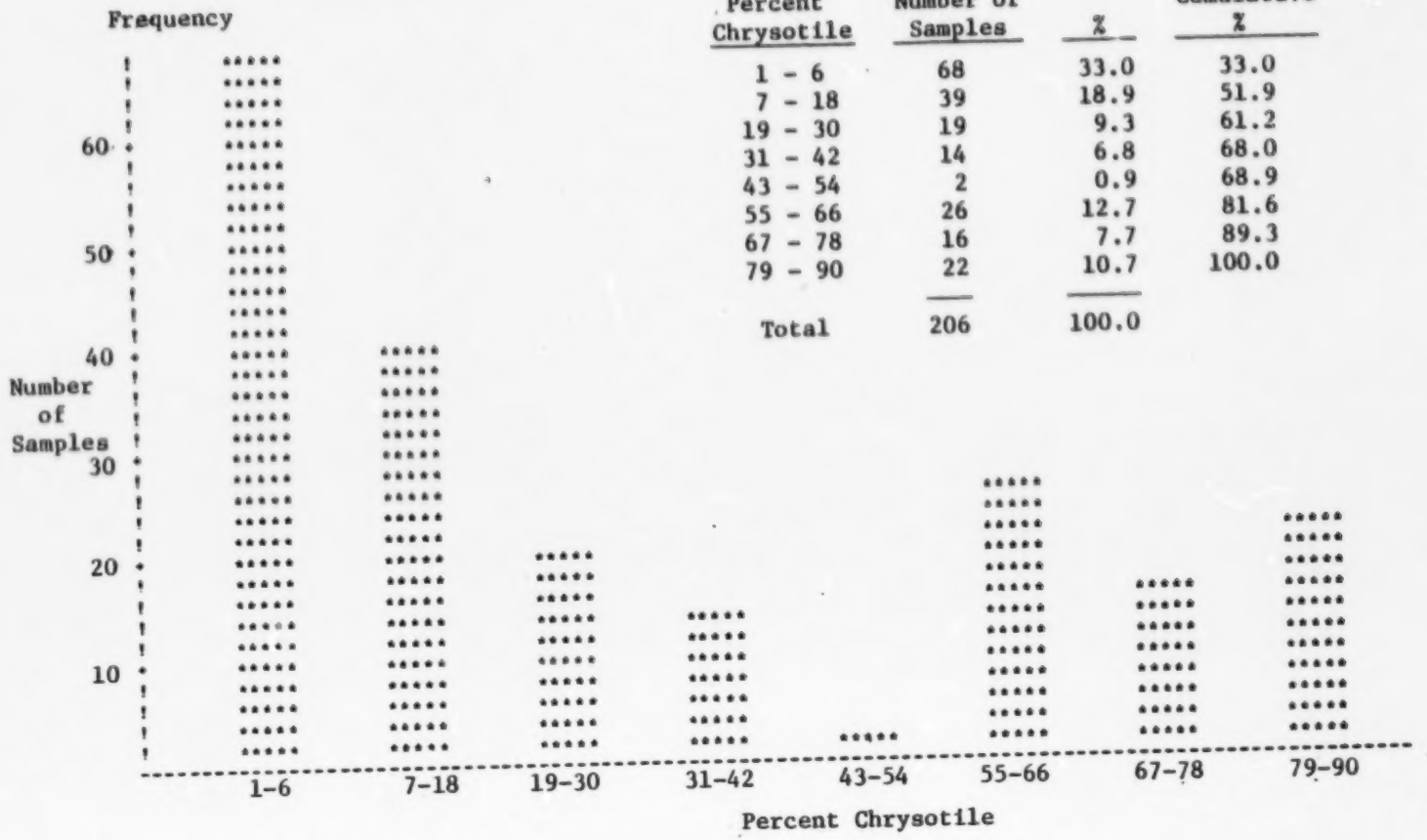
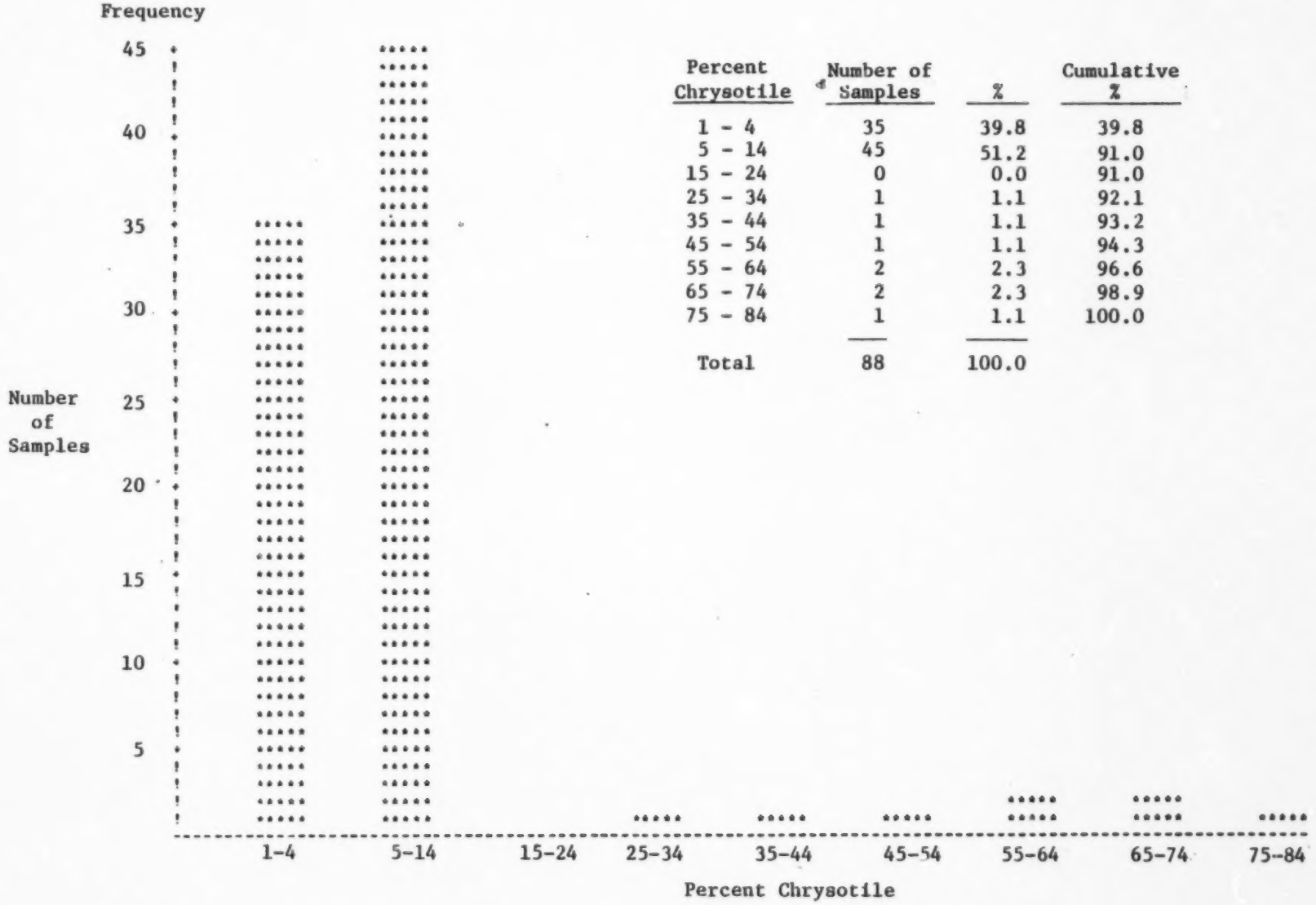


Figure I.3.A. Distribution of the Percent Chrysotile in the 206 Friable and Non-Friable Samples Containing Chrysotile



Percent Chrysotile	Number of Samples	%	Cumulative %
1 - 4	35	39.8	39.8
5 - 14	45	51.2	91.0
15 - 24	0	0.0	91.0
25 - 34	1	1.1	92.1
35 - 44	1	1.1	93.2
45 - 54	1	1.1	94.3
55 - 64	2	2.3	96.6
65 - 74	2	2.3	98.9
75 - 84	1	1.1	100.0
Total	88	100.0	

Figure I.3.B. Distribution of the Percent Chrysotile in the 88 Non-Friable Samples Containing Chrysotile

Percent Chrysotile	Number of Samples	%	Cumulative %
1 - 6	7	5.9	5.9
7 - 18	20	17.0	22.9
19 - 30	18	15.2	38.1
31 - 42	13	11.1	49.2
43 - 54	1	0.8	50.0
55 - 66	24	20.3	70.3
67 - 78	14	11.9	82.2
79 - 90	21	17.8	100.0
Total	118	100.0	

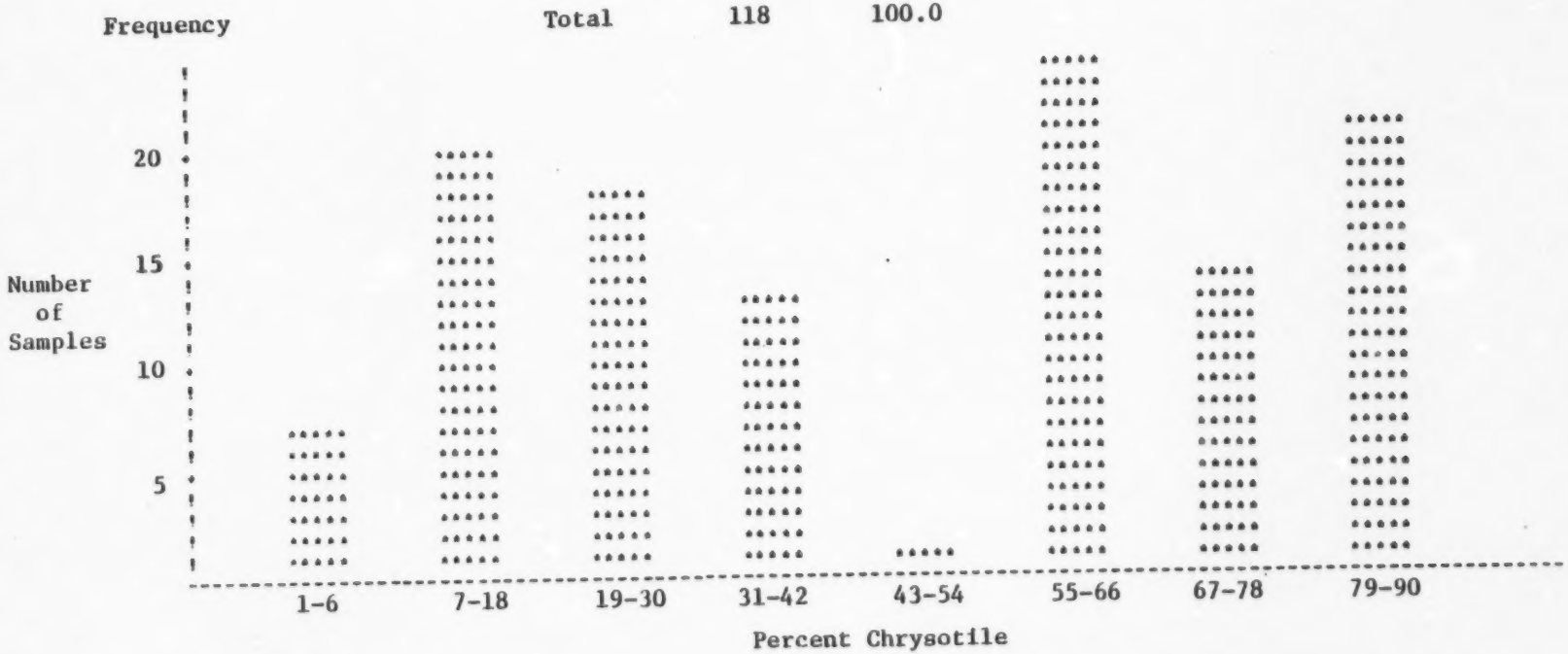


Figure I.3.C. Distribution of the Percent Chrysotile in the 118 Friable Samples Containing Chrysotile

APPENDIX I.A

CODES FOR THE ASBESTOS DATA

TYPEMAT - Type of Material

1 Acoustic Plaster
Acoustic Plaster - Hard
Acoustic Plaster - Soft
Cement Plaster
Plaster - Light - Dense
Textured Plaster

2 Beam Fireproofing
Fireproofing
Soft Spray-on Fireproofing
Spray Fireproofing

3 Acoustic Material
Acoustic Material (Soft)
Acoustic Spray (Hard)
Acoustic Spray (Soft)
Insulation on Conc.
Soft Asbestos
Soft Fiber
Soft Material Insulation
Soft Spray-on Material
Spray-on Asbestos
Spray-on Fibers
Spray-on Insulation
Spray-on Material
Thermal Insulation (Soft)
Thermal Material

TYPEMAT - Type of Material

4 Acoustic Board
Acoustic Paint
Acoustic Tile
Asbestos Covering
Asbestos Heating Insulation (Soft)
Asbestos Pipe Covering
Boiler Breeching
Boiler Insulation
Boiler Jacket #3
Breeching Material
Cabinet Backing
Cabinet Lining
Cem. Asb. Lay-in Tile
Chimney Breeching
Duct Cover (Insulation)
Heating Insulation
Insulation
Pipe Covering
Pipe Insulation
Soft Asbestos Covering
Soft Plaster Back for Acoustic Tile
Tank Jacket
Thermal Insulation
Transite Fiberboard
Vent Hood Insulation

ASBESTOS - Was any asbestos in the sample?

1 No
2 Yes

PCTASB1 - Percent of first type of asbestos in the sample

TYPEASB1 - First type of asbestos in the sample

1 Amosite
2 Chrysotile
3 Crocidolite

PCTASB2 - Percent of second type of asbestos in the sample

TYPEASB2 - Second type of asbestos in the sample

1 Amosite
2 Chrysotile
3 Crocidolite

TOTPCTAS - Total percent asbestos in the sample

DATA LISTING

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Sample Number	TYPEMAT	ASBESTOS	PCTASB1	TYPEASB1	PCTASB2	TYPEASB2	TOTPCTAS
1	3	1	0		0		0
2	2	1	0		0		0
3	3	2	60	1	0		60
4	1	1	0		0		0
5	4	1	0		0		0
6	1	1	0		0		0
7	2	2	30	2	0		30
8	3	2	30	3	0		30
9	3	2	30	2	0		30
10	1	1	0		0		0
11	2	1	0		0		0
12	1	1	0		0		0
13	1	1	0		0		0
14	1	2	3	2	0		3
15	1	2	40	2	0		40
16	1	1	0		0		0
17	2	2	5	2	0		5
18	4	1	0		0		0
19	1	1	0		0		0
20	1	2	3	2	0		3
21	4	1	0		0		0
22	4	1	0		0		0
23	4	1	0		0		0
24	3	2	70	2	0		70
25	2	2	35	2	0		35
26	4	1	0		0		0
27	1	1	0		0		0
28	4	1	0		0		0
29	3	2	30	2	0		30
30	2	2	65	2	0		65
31	1	2	1	2	0		1
32	1	1	0		0		0
33	1	1	0		0		0
34	4	2	25	2	0		25
35	1	1	0		0		0
36	4	2	20	2	0		20
37	1	1	0		0		0
38	4	1	0		0		0
39	3	1	0		0		0
40	4	2	5	2	0		5
41	1	1	0		0		0
42	4	2	78	2	0		78
43	3	2	60	2	0		60
44	4	2	10	2	0		10
45	1	1	0		0		0
46	2	2	7	1	0		7
47	1	1	0		0		0
48	1	1	0		0		0
49	1	1	0		0		0
50	1	1	0		0		0
51	2	2	80	2	0		80
52	1	1	0		0		0
53	1	1	0		0		0
54	1	1	0		0		0

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Sample Number	TYPEMAT	ASBESTOS	PCTASB1	TYPEASB1	PCTASB2	TYPEASB2	TOTPCTAS
55	1	2	3	2	0		3
56	1	1	0		0		0
57	2	2	30	2	0		30
58	1	1	0		0		0
59	4	2	60	2	0		60
60	1	1	0		0		0
61	4	1	0		0		0
62	3	2	7	2	0		7
63	1	1	0		0		0
64	1	2	3	2	0		3
65	1	1	0		0		0
66	4	2	78	2	0		78
67	3	1	0		0		0
68	1	1	0		0		0
69	1	1	0		0		0
70	1	1	0		0		0
71	4	1	0		0		0
72	4	2	10	2	0		10
73	1	1	0		0		0
74	1	1	0		0		0
75	1	2	7	2	0		7
76	1	1	0		0		0
77	1	1	0		0		0
78	1	1	0		0		0
79	2	1	0		0		0
80	1	1	0		0		0
81	1	2	5	2	0		5
82	1	2	5	2	0		5
83	1	1	0		0		0
84	1	1	0		0		0
85	1	1	0		0		0
86	1	1	0		0		0
87	1	1	0		0		0
88	1	1	0		0		0
89	1	2	5	2	0		5
90	1	2	5	2	0		5
91	1	1	0		0		0
92	1	1	0		0		0
93	1	1	0		0		0
94	3	2	70	2	0		70
95	3	2	70	2	0		70
96	1	2	3	1	0		3
97	1	2	10	2	0		10
98	1	2	5	2	0		5
99	1	1	0		0		0
100	1	1	0		0		0
101	1	1	0		0		0
102	1	1	0		0		0
103	2	1	0		0		0
104	1	1	0		0		0
105	1	1	0		0		0
106	2	2	10	2	0		10
107	1	1	0		0		0
108	1	2	7	2	0		7

Sample Number	TYPEMAT	ASBESTOS	PCTAS-1	TYPEASB1	PCTASB2	TYPEASB2	TOTPCTAS
109	1	1	0		0		0
110	1	1	0		0		0
111	1	1	0		0		0
112	1	1	0		0		0
113	1	1	0		0		0
114	1	1	0		0		0
115	1	1	0		0		0
116	1	2	60	2	0		60
117	2	2	70	1	0		70
118	2	2	65	2	0		65
119	1	1	0		0		0
120	1	1	0		0		0
121	2	2	7	2	0		7
122	1	2	7	2	0		7
123	1	2	80	1	0		80
124	1	2	40	1	0		40
125	2	2	30	2	0		30
126	1	1	0		0		0
127	1	1	0		0		0
128	1	1	0		0		0
129	1	2	7	2	0		7
130	1	1	0		0		0
131	1	1	0		0		0
132	1	1	0		0		0
133	1	2	3	2	0		3
134	1	1	0		0		0
135	1	2	5	2	0		5
136	1	2	5	2	0		5
137	1	1	0		0		0
138	2	2	60	1	0		60
139	2	2	3	2	0		3
140	2	2	40	2	0		40
141	1	1	0		0		0
142	1	1	0		0		0
143	1	2	3	2	0		3
144	1	2	5	2	0		5
145	1	1	0		0		0
146	1	2	5	2	0		5
147	2	2	7	1	0		7
148	1	1	0		0		0
149	1	1	0		0		0
150	1	1	0		0		0
151	1	2	5	2	0		5
152	2	2	10	1	10	2	20
153	1	2	1	1	1	2	2
154	1	2	1	2	0		1
155	1	1	0		0		0
156	1	1	0		0		0
157	1	1	0		0		0
158	1	2	5	2	0		5
159	2	2	12	1	36	2	48
160	1	1	0		0		0
161	1	2	15	1	0		15
162	1	2	70	2	0		70

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Sample Number	TYPEMAT	ASBESTOS PCTASB1	TYPEASB1	PCTASB2	TYPEASB2	TOTPCTAS
163	1	2	2	1	0	2
164	1	1	0			0
165	1	1	0			0
166	1	2	1	1	0	1
167	1	1	0			0
168	1	1	0			0
169	1	2	1	2	0	1
170	2	2	8	1	3	2 11
171	2	2	8	1	8	2 16
172	2	2	65	2	0	65
173	4	2	18	2	0	18
174	1	2	6	2	0	6
175	2	2	30	1	0	30
176	1	1	0			0
177	1	1	0			0
178	1	2	1	2	0	1
179	1	1	0			0
180	2	2	5	2	0	5
181	2	2	40	2	0	40
182	2	1	0			0
183	2	2	25	2	0	25
184	2	2	40	2	0	40
185	1	1	0			0
186	1	1	0			0
187	1	2	5	2	0	5
188	1	1	0			0
189	1	1	0			0
190	1	2	5	2	0	5
191	2	2	70	2	0	70
192	1	2	7	2	0	7
193	1	2	5	2	0	5
194	2	1	0			0
195	2	2	60	2	0	60
196	1	1	0			0
197	2	2	65	2	20	1 85
198	1	2	5	2	0	5
199	2	2	70	1	0	70
200	1	1	0			0
201	2	2	65	2	0	65
202	1	2	5	2	0	5
203	1	2	3	2	0	3
204	1	1	0			0
205	1	2	5	2	0	5
206	1	1	0			0
207	4	2	75	2	0	75
208	4	2	75	2	0	75
209	4	2	80	2	0	80
210	1	1	0			0
211	1	2	6	2	0	6
212	1	2	7	2	0	7
213	2	2	15	2	0	15
214	4	2	30	2	0	30
215	1	2	3	2	0	3
216	1	2	3	2	0	3

DATA LISTING

Sample Number	TYPEMAT	ASBESTOS	PCTASB1	TYPEASB1	PCTASB2	TYPEASB2	TOTPCTAS
217	3	2	10	2	0		10
218	1	1	0		0		0
219	2	1	0		0		0
220	1	1	0		0		0
221	1	1	0		0		0
222	1	2	1	2	0		1
223	3	1	0		0		0
224	1	2	2	2	0		2
225	1	1	0		0		0
226	1	1	0		0		0
227	4	2	30	2	0		30
228	2	2	6	1	0		6
229	1	1	0		0		0
230	1	1	0		0		0
231	1	1	0		0		0
232	1	1	0		0		0
233	1	1	0		0		0
234	1	2	1	2	0		1
235	1	1	0		0		0
236	4	2	65	2	0		65
237	1	2	1	2	0		1
238	4	2	35	2	0		35
239	1	1	0		0		0
240	4	2	40	2	10	1	50
241	1	1	0		0		0
242	1	1	0		0		0
243	2	1	0		0		0
244	2	1	0		0		0
245	2	2	15	1	0		15
246	2	2	85	2	0		85
247	3	1	0		0		0
248	2	2	80	2	0		80
249	1	1	0		0		0
250	1	2	1	2	0		1
251	1	1	0		0		0
252	2	2	20	1	0		20
253	1	1	0		0		0
254	4	2	85	2	0		85
255	4	2	60	2	0		60
256	4	2	70	2	12	1	82
257	1	2	5	2	0		5
258	4	2	85	2	0		85
259	2	1	0		0		0
260	4	2	70	2	0		70
261	1	2	8	2	0		8
262	3	1	0		0		0
263	2	2	85	2	0		85
264	2	2	45	2	0		45
265	1	1	0		0		0
266	3	2	15	1	15	2	30
267	4	2	80	2	0		80
268	1	1	0		0		0
269	4	2	60	2	0		60
270	4	2	40	2	10	1	50

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Sample Number	TYPEMAT	ASBESTOS	PCTASB1	TYPEASB1	PCTASB2	TYPEASB2	TOTPCTAS
271	4	2	15	1	0		15
272	2	2	20	2	0		20
273	4	2	40	2	0		40
274	4	2	55	2	0		55
275	1	1	0		0		0
276	1	2	2	2	0		2
277	1	2	8	2	0		8
278	1	1	0		0		0
279	4	2	15	2	0		15
280	2	2	30	2	0		30
281	1	1	0		0		0
282	2	2	35	2	0		35
283	1	1	0		0		0
284	1	1	0		0		0
285	1	2	2	2	0		2
286	1	1	0		0		0
287	1	1	0		0		0
288	1	2	3	2	0		3
289	1	1	0		0		0
290	1	1	0		0		0
291	1	2	45	2	0		45
292	2	2	70	2	25	1	95
293	1	1	0		0		0
294	1	1	0		0		0
295	1	1	0		0		0
296	2	2	20	2	0		20
297	1	2	10	2	0		10
298	1	2	3	2	0		3
299	3	1	0		0		0
300	3	2	20	2	10	1	30
301	4	2	65	2	7	1	72
302	1	1	0		0		0
303	1	1	0		0		0
304	1	2	5	2	0		5
305	2	2	25	2	0		25
306	1	2	5	2	0		5
307	1	1	0		0		0
308	4	2	75	1	0		75
309	4	2	18	2	0		18
310	2	2	80	2	0		80
311	1	1	0		0		0
312	1	2	3	2	0		3
313	4	2	60	2	0		60
314	1	2	60	2	0		60
315	1	1	0		0		0
316	2	1	0		0		0
317	1	2	8	2	0		8
318	1	2	10	2	0		10
319	4	2	15	2	0		15
320	4	1	0		0		0
321	2	2	80	2	0		80
322	1	2	10	2	0		10
323	1	1	0		0		0
324	2	2	4	2	0		4

Sample Number	TYPEMAT	ASBESTOS	PCTASB1	TYPEASB1	PCTASB2	TYPEASB2	TOTPCTAS
325	1	1	0		0		0
326	1	2	5	2	0		5
327	1	1	0		0		0
328	1	1	0		0		0
329	4	2	75	2	0		75
330	1	1	0		0		0
331	4	2	79	2	0		79
332	1	1	0		0		0
333	2	2	3	2	0		3
334	1	1	0		0		0
335	1	1	0		0		0
336	1	1	0		0		0
337	2	2	10	2	0		10
338	1	1	0		0		0
339	2	1	0		0		0
340	1	1	0		0		0
341	2	2	60	2	0		60
342	1	1	0		0		0
343	1	1	0		0		0
344	3	2	15	2	0		15
345	1	1	0		0		0
346	1	1	0		0		0
347	1	1	0		0		0
348	1	2	5	2	0		5
349	1	1	0		0		0
350	1	1	0		0		0
351	1	1	0		0		0
352	3	2	10	2	0		10
353	1	1	0		0		0
354	1	2	55	2	0		55
355	3	2	20	2	0		20
356	1	1	0		0		0
357	1	1	0		0		0
358	1	1	0		0		0
359	2	1	0		0		0
360	2	2	85	2	0		85
361	1	2	80	2	0		80
362	2	2	65	2	0		65
363	1	1	0		0		0
364	1	2	5	2	0		5
365	3	2	60	1	0		60
366	3	2	75	2	0		75
367	4	2	80	2	0		80
368	1	1	0		0		0
369	1	1	0		0		0
370	1	1	0		0		0
371	1	1	0		0		0
372	1	1	0		0		0
373	1	1	0		0		0
374	1	1	0		0		0
375	1	1	0		0		0
376	1	1	0		0		0
377	1	1	0		0		0
378	4	2	5	2	0		5

Sample Number	TYPEMAT	ASBESTOS	PCTASB1	TYPEASB1	PCTASB2	TYPEASB2	TOTPCTAS
379	4	2	40	2	0		40
380	1	2	3	2	0		3
381	1	2	7	2	0		7
382	1	2	5	2	0		5
383	4	2	70	2	0		70
384	4	2	33	1	0		33
385	2	2	20	1	0		20
386	1	2	3	2	0		3
387	1	2	70	2	0		70
388	1	1	0		0		0
389	4	2	80	1	0		80
390	1	1	0		0		0
391	4	1	0		0		0
392	1	2	8	2	0		8
393	4	2	10	1	0		10
394	2	2	15	2	0		15
395	4	1	0		0		0
396	4	2	60	2	0		60
397	1	2	1	2	0		1
398	1	2	8	2	0		8
399	4	2	12	1	0		12
400	2	2	65	2	0		65
401	1	2	3	2	0		3
402	1	1	0		0		0
403	1	1	0		0		0
404	1	2	1	2	0		1
405	1	1	0		0		0
406	4	2	65	2	0		65
407	1	1	0		0		0
408	1	1	0		0		0
409	4	2	40	2	0		40
410	2	2	15	2	0		15
411	4	2	65	2	0		65
412	4	2	65	2	0		65
413	1	1	0		0		0
414	1	1	0		0		0
415	4	1	0		0		0
416	1	1	0		0		0
417	1	1	0		0		0
418	1	2	1	2	0		1
419	2	1	0		0		0
420	1	1	0		0		0
421	4	1	0		0		0
422	1	1	0		0		0
423	1	1	0		0		0
424	2	2	25	2	12	1	37
425	1	1	0		0		0
426	1	1	0		0		0
427	4	1	0		0		0
428	1	1	0		0		0
429	1	2	7	2	0		7
430	2	2	90	2	0		90
431	1	1	0		0		0
432	1	1	0		0		0

Sample Number	TYPEMAT	ASBESTOS	PCTASB1	TYPEASB1	PCTASB2	TYPEASB2	TOTPCTAS
433	4	2	40	2	0		40
434	1	1	0		0		0
435	1	1	0		0		0
436	1	1	0		0		0
437	1	1	0		0		0
438	1	1	0		0		0
439	4	2	30	1	0		30
440	1	2	1	2	0		1
441	1	1	0		0		0
442	4	1	0		0		0
443	4	2	85	2	0		85
444	1	2	5	2	0		5
445	4	2	85	2	0		85
446	4	2	80	2	0		80
447	4	2	80	2	0		80
448	4	2	75	1	0		75
449	4	2	60	2	8	1	68
450	2	2	20	2	0		20
451	1	1	0		0		0
452	4	2	5	1	0		5
453	1	1	0		0		0
454	1	2	30	2	0		30
455	4	2	8	2	8	1	16
456	1	2	5	2	0		5
457	1	1	0		0		0
458	4	2	80	2	0		80
459	3	1	0		0		0
460	1	1	0		0		0
461	1	1	0		0		0
462	1	2	2	2	0		2
463	4	2	60	2	0		60
464	1	1	0		0		0
465	2	2	80	2	0		80
466	1	2	3	2	0		3
467	1	1	0		0		0
468	1	1	0		0		0
469	4	2	90	1	0		90
470	1	1	0		0		0
471	4	2	90	2	0		90
472	1	2	3	2	0		3
473	2	1	0		0		0
474	1	1	0		0		0

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II. MARYLAND

Data Supplied By:

Dr. Max Eisenberg

Division of Health and Mental Hygiene
Environmental Health Administration
State of Maryland

II.1 Introduction

The State of Maryland has developed an asbestos survey program for its public schools in response to the recently identified hazards of some building materials. The actual identification and quantitation of processed asbestos is not a routine or simple matter. Discrepancies are not uncommon between analytical laboratories analyzing the same sample. This situation exists in part because the determination of asbestos is a relatively new technique for some facilities and there is as yet no standard analytical protocol or universal reference material available.

Nevertheless, the need to ascertain the mineral content of sprayed insulation materials, pipe insulation, and the like is of central importance to a preventative measures program. If the material is falsely identified as positive for asbestos, there will be an unnecessary expenditure of funds for remedial action and a loss of confidence in the program when this is discovered. If the material is falsely identified as negative for asbestos, exposure to the potential health hazard is left unresolved.

Considering the costs involved and the current level of public concern, asbestos must be identified with a high degree of certainty. To this end the State of Maryland health officials have employed three competent laboratories and sent split-samples to two or more of the facilities. Only those results which show agreement between laboratories are considered valid in their initial survey and worthy of recommendations for action. The following is a listing and analysis of data from the first phase of this comparative testing program.

II.2 Data

The data set consists of the laboratory determinations of two types of asbestos (amphibole and chrysotile) by three laboratories (Maryland Geological Survey (MGS), Occupational Health Laboratory (OCCH), and Maryland Mineral Associates (MDMA)) on 37 samples. A listing of the data is given in Table II.1 (eighty-six lab reports in all).

The table shows that

(a) all three laboratories reported data on 10 samples (samples 1, 11, 12, 14, 15, 19, 21, 24, 25 and 30),

(b) lab determinations by at least two of the three laboratories were done on all but three samples (55, 80 and 85),

(c) the Maryland Geological Survey lab reported data on all except two samples (80 and 85), and also reported two determinations each on five samples (12, 14, 19, 24 and 25),
(d) the Occupational Health Laboratories reported data on thirty samples, and
(e) the Maryland Mineral Associates (MDMA) lab reported data only on fourteen samples.

The laboratory reports include an overall assessment on presence or absence of asbestos for each of the samples analyzed by that laboratory.

The following conventions and modifications were used in converting the data into computer readable form:

1. "____" was treated as zero
2. When a range is provided by a lab, the mean value of this range was used.

For those readers not interested in the statistical details, Section II.5 (page __) presents the summary and conclusions of the analysis.

II.3 Statistical Methodology

II.3.1 Introduction

The data were essentially analyzed in two ways:

1. To determine if there were differences between labs with regard to presence or absence of asbestos, and
2. To determine if there were differences between labs with regard to the actual amount (level) of asbestos found.

Within each of these two basic analyses tests were performed on two groups of samples; namely those samples with data on all three labs and samples with data on only two labs at one time.

II.3.2 Model

The data were analyzed with a view to determining whether the differences among the laboratories with respect to presence/absence or amount of asbestos were statistically significant. The data were analyzed using both an analysis of variance approach and nonparametic approaches based on ranks. The following basic model was employed for the analysis:

$$Y_{ij} = \mu + L_i + S_j + \varepsilon_{ij}$$

where

Y_{ij} is the laboratory determination (amphibole or chrysotile) of the presence/absence or amount of asbestos in the j^{th} sample at the i^{th} laboratory;

μ is a constant term;

L_i ($\Sigma L_i = 0$) is the effect associated with the i^{th} laboratory;

S_j ($\Sigma S_j = 0$) is the effect associated with the j^{th} sample; and

ε_{ij} is an error term.

The ε_{ij}'s are assumed to be independent indentically distributed random variables. The analysis of variance approach assumes that the ε_{ij}'s have a normal distribution with mean zero and standard deviation = σ_e^2. The nonparametric method assumes that the ε_{ij}'s come from a continuous population. Thus the assumptions on the ε_{ij}'s are less stringent for the nonparametric approach. In both types of analysis, the null hypothesis is the equality of laboratory effects,

$L_1 = L_2 = L_3$; i.e., is percent present or the level of asbestos found the same for each of the labs.

II.3.3 Analysis of Variance (ANOVA)

The data on all the 37 samples (excluding the data on the second determination on five samples at MGS) were used for this analysis. The ANOVA was only used to test that the amount of asbestos was the same for the various labs and to estimate measurement errors.

A separate analysis of variance was carried out with the data on the five MGS samples with duplicate determinations for the purpose of estimating measurement errors.

II.3.4 Nonparametric Methods

The significance of the differences among laboratory levels of asbestos was examined with the data from the ten samples analyzed by all the three laboratories. The sample was treated as a "block" and the data were analyzed like a randomized block design with three treatments and ten blocks using the rank order statistic proposed by Friedman (see pages 262-265 of the reference). For each sample, the amounts of asbestos for laboratories were ranked (separately for chrysotile and amphibole) from one to three and these ranks were analyzed using the procedure.

The differences between pairs of laboratories for amounts of asbestos were analyzed using all the samples with determinations from both the laboratories of the pair. The number of samples available for these pairwise comparisons are 30 for MGS vs. OCCH, 14 for MGS vs. MDM and 10 for OCCH vs. MDM. The data were analyzed using the Wilcoxon signed-rank Test (see pages 124 - 131 of the text referenced) using a normal approximation.

The data on presence or absence of asbestos on the ten samples analyzed at all the laboratories were analyzed using the Cochran statistic (see page 267 of the text referenced). The McNemear Test (see page 268 of the text referenced) was used to compare pairs of laboratories on the presence or absence of asbestos.

II.4 Results

II.4.1 Comparisons of the Data on Presence/Absence of Asbestos Among Labs

There were no disagreements in presence/absence of asbestos between the duplicate determinations made by MGS on the five samples (12, 14, 19, 24, and 25).

The distribution of the data on the ten samples analyzed by all the three labs is as follows:

	No. of Samples
All reported asbestos present	6
All reported asbestos absent	1
Two labs reported asbestos present	2*
Two labs reported asbestos absent	1**
Total	10

* For samples 12 & 14 MGS and MDMA reported asbestos present while OCCH reported asbestos absent

** For sample 1 OCCH and MDMA reported asbestos absent while MGS reported asbestos present

This data was analyzed to test the difference among the three labs with respect to their assessment of presence or absence of asbestos using the Cochran procedure (see page 267 of the reference). The differences were not significant at the 0.05 level (test statistic of 4.667, P = 0.10).

The distribution of the data on the 24 samples analyzed by only two laboratories is as follows:

Both reported asbestos	11
Both reported no asbestos	13
Total	24

Thus, there were no disagreements between the pairs of labs involved in the analysis of these twenty-four samples.

The cross tabulations of the data, on all the 34 samples analyzed by at least two labs, for pairs of labs are given in Tables II.2a, II.2b, and II.2c. None of the differences are statistically significant (by the McNemear Test).

To sum up, there were disagreements between the laboratories only in three of the 34 (8.8%) samples. The differences among the labs was not significant at the 0.05 level.

II.4.2 Summary Statistics

Table II.3 presents the summary statistics for the determinations of levels of asbestos made by each of the laboratories. Note that since all laboratories did not analyze all the samples, the comparison of laboratories based on these summary statistics may be misleading.

II.4.3 Comparisons of Laboratory Determinations Among Laboratories

The test statistics related to the comparison of laboratories are given in Tables II.4 and II.5.

The Friedman statistics in Table II.4 are based on the data on the ten samples analyzed by all the three laboratories. We note that the differences among the laboratories are significant at the 0.05 level for chrysotile determinations.

The test statistics based on the Wilcoxon signed-rank sum procedure for pairwise comparisons of the labs are given in Table II.5. We note that the differences between MGS and MDMA are significant for both chrysotile and amphibole. Compared to the determinations at MGS, the % asbestos level determinations at MDMA are significantly lower for chrysotile and higher for amphibole.

II.4.4 Analysis of Variance

The ANOVA on the differences between labs on levels of asbestos for all 37 samples was not statistically significant. However, the assumptions underlying this analysis are suspect (e.g., the data is not normally distributed); and therefore, the non-parametric analyses given above are probably more appropriate.

The estimates of the measurement errors using ANOVA and other summary statistics are given in Table II.6. The square-root of the residual mean square error under the model is shown as the measurement error in the table. The measurement error is an estimate of the variability of repeated measurements on the same sample.

II.5 Summary and Conclusions

The data on presence/absence of asbestos were analyzed to determine whether there were differences among the laboratories. There were disagreements between the labs only in three of the 34 (8.8%) samples analyzed by two or more labs. Tests of significance between labs for presence or absence of asbestos using the Cochran procedure or the McNemear Test were not significant.

The data on laboratory % asbestos levels of chrysotile and amphibole carried out by three laboratories on 37 samples were also analyzed with a view to determine whether there were any differences among the laboratories. The analysis indicated that there were differences between MGS and MDMA. Compared to the laboratory levels at MGS, the % asbestos levels by MDMA were lower for chrysotile and higher for amphibole. Thus, % asbestos levels difference between labs were noted but lab differences on the presence/absence of asbestos were not significant.

REFERENCE

Lehman, E.L., "Nonparametrics: Statistical Methods Based on Ranks", Holden-Day, Inc., San Francisco, 1975.

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Table II.1 DATA LISTING

SAMPLE	LAB	CHRY	AMPH	PRESENT
1	MDMA	0.0	0.0	NO
1	MGS1	0.5	0.0	YES
1	OCCH	0.0	0.0	NO
2	MGS1	45.0	12.5	YES
2	OCCH	30.0	30.0	YES
3	MGS1	0.0	0.0	NO
3	OCCH	0.0	0.0	NO
4	MGS1	0.0	0.0	NO
4	OCCH	0.0	0.0	NO
5	MGS1	30.0	45.0	YES
5	OCCH	25.0	25.0	YES
6	MGS1	35.0	20.0	YES
6	OCCH	15.0	15.0	YES
7	MGS1	0.0	0.0	NO
7	OCCH	0.0	0.0	NO
8	MGS1	0.0	0.0	NO
8	OCCH	0.0	0.0	NO
10	MGS1	0.0	0.0	NO
10	OCCH	0.0	0.0	NO
11	MDMA	2.5	1.5	YES
11	MGS1	7.5	0.0	YES
11	OCCH	0.0	10.0	YES
12	MDMA	0.0	10.0	YES
12	MGS1	15.0	0.0	YES
12	MGS1	10.0	0.0	YES
12	OCCH	0.0	0.0	NO
13	MGS1	0.0	0.0	NO
13	OCCH	0.0	0.0	NO
14	MDMA	0.0	10.0	YES
14	MGS1	25.0	0.0	YES
14	MGS1	30.0	0.0	YES
14	OCCH	0.0	0.0	NO
15	MDMA	0.5	0.0	YES
15	MGS1	1.5	0.0	YES
15	OCCH	5.0	10.0	YES
16	MGS1	0.0	0.0	NO
16	OCCH	0.0	0.0	NO
17	MGS1	30.0	0.0	YES
17	OCCH	30.0	0.0	YES
18	MGS1	0.0	0.0	NO
18	OCCH	0.0	0.0	NO
19	MDMA	90.0	0.0	YES
19	MGS1	100.0	0.0	YES
19	MGS1	100.0	0.0	YES
19	OCCH	50.0	0.0	YES
20	MGS1	0.0	0.0	NO
20	OCCH	0.0	0.0	NO
21	MDMA	0.5	0.0	YES
21	MGS1	7.5	0.0	YES
21	OCCH	5.0	0.0	YES
22	MGS1	0.0	0.0	NO
22	OCCH	0.0	0.0	NO
23	MGS1	25.0	0.0	YES
23	OCCH	37.5	0.0	YES
24	MDMA	0.0	0.0	NO
24	MGS1	0.0	0.0	NO

Table II.1(Continued)

SAMPLE	LAB	CHRY	AMPH	PRESENT
24	MGSL	0.0	0.0	NO
24	OCCH	0.0	0.0	NO
25	MDMA	0.0	1.5	YES
25	MGSL	1.0	0.0	YES
25	MGSL	1.5	0.0	YES
25	OCCH	0.0	10.0	YES
25	MGSL	17.5	0.0	YES
25	OCCH	42.5	0.0	YES
30	MDMA	35.0	0.0	YES
30	MGSL	40.0	0.0	YES
30	OCCH	35.0	0.0	YES
35	MDMA	0.0	0.0	NO
35	MGSL	0.0	0.0	NO
40	MDMA	40.0	0.0	YES
40	MGSL	25.0	0.0	YES
45	MDMA	0.0	0.0	NO
45	MGSL	0.0	0.0	NO
50	MDMA	0.0	0.0	NO
50	MGSL	0.0	0.0	NO
55	MGSL	0.0	0.0	NO
60	MGSL	0.0	70.0	YES
60	OCCH	0.0	90.0	YES
65	MGSL	0.0	70.0	YES
65	OCCH	0.0	90.0	YES
70	MGSL	25.0	0.0	YES
70	OCCH	45.0	0.0	YES
75	MGSL	15.0	0.0	YES
75	OCCH	80.0	0.0	YES
80	OCCH	0.0	0.0	NO
85	OCCH	20.0	40.0	YES

Table II.2. PRESENCE OF ASBESTOS BY LABORATORIES

(a) MGS vs OCCH

		OCCH		
		No	Yes	Total
MGS	No	11	0	11
	Yes	3	16	19
	Total	14	16	30

(b) MGS vs MDMA

		MDMA		
		No	Yes	Total
MGS	No	4	0	4
	Yes	1	9	10
	Total	5	9	14

(c) OCCH vs MDMA

		MDMA		
		No	Yes	Total
OCCH	No	2	2	4
	Yes	0	6	6
	Total	2	8	10

Table II.3. SUMMARY STATISTICS ON LEVELS OF ASBESTOS BY LABORATORY

Laboratory	Asbestos Type	No. of Determinations	Mean (%)	Standard Deviation (%)	Coefficient** of Variation
MDMA	Amphibole	14	1.64	3.58	85
	Chrysotile	14	12.04	26.17	125
MGS*	Amphibole	35	6.21	18.01	62
	Chrysotile	35	12.73	20.55	93
OCCH	Amphibole	32	10.0	23.17	92
	Chrysotile	32	13.13	20.44	63

* MGS data includes duplicate determinations on 5 samples. Only one of these determinations are included here.

** Based on determinations which are non-zero.

Table II.4. TEST STATISTIC* BASED ON FRIEDMAN PROCEDURE FOR COMPARING LEVELS OF ASBESTOS FOR THE THREE LABORATORIES

Determination	Test Statistic	P-Value
Chrysotile	12.45	< 0.025
Amphibole	4.35	< 0.12

* The formula for use in presence of ties is used here (see pages 265 of the reference cited).

Table II.5. TEST STATISTIC BASED ON WILCOXON SIGNED RANK SUM PROCEDURE FOR COMPARING LEVELS OF ASBESTOS FOR PAIRS OF LABORATIRIES

Comparison	Chrysotile	Amphibole	No. of Samples
MGS vs OCCH	1.219	- 1.436	30
MGS vs MDMA	2.0989*	- 1.9936*	14
OCCH vs MDMA	0	0.2210	10

* Significant at 0.05 level (2-tail test).

The formula for use in presence of ties is used here (see pages 130-131 of the reference cited).

Table II.6. RESULTS BASED ON ANOVA

Asbestos Type	Mean (%)	Measurement Error[1/] (%)	Coefficient of Variation
Amphibole	6.5174	4.6860[2/]	71.9
Chrysotile	13.6686	11.1123[2/]	81.3
Chrysotile[+]	35.31	2.5061[++]	7.10

1/ Square root of the residual mean square error under the model.

2/ Based on 37 samples.

\+ Data on only five duplicate analyses in Maryland Geological Survey Lab.

++ This is an estimate of the within laboratory variability for Chrysotile. Amphibole determinations were all zero.